Working Paper 77-11-01

ENERGY FUTURES: Scenarios and Perturbations

A demonstration of the Statistics Canada
Long Term Simulation Model

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November 1977

Preface

The style of this paper is deliberately terse, in the hope that a wider audience may be reached by a thinner document. Should the reader have questions or comments or wish amplification of any of the points dealt with here, he/she is sincerely invited to contact one of the authors (telephone 995-0641 or 995-0635).

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I INTRODUCTION

Governments must always be concerned with achieving the goal of long term economic stability. To aid them in the decision making process, a large number of forecasting models have been designed and utilized with varying degrees of success. In recent years another element has come to the fore as a major consideration, that of rapidly depleting world reserves of energy and other non-renewable resources.

The Long Term Simulation Model (hereafter referred to by the acronym LTSM) represents an attempt to deal with this second consideration as well as to provide a method for simulating various economic growth scenarios. The approach taken to accomplish these objectives is in sharp contrast to more traditional economic models which explain the evolution of the economic system as a function of the behavior of economic agents under the assumption that whatever is required from the physical system is available. This model, rather, places emphasis on modelling the flows of materials within the economic system and the ways in which these materials are transformed into finished products. We wish to ensure that these flows and transformations are feasible from the point of view of availability and the physical laws that govern transformations.

This emphasis on physical flows within the economic system requires, first of all, that the flows be disaggregated by kind of material. It is evident that the supplies of various materials in the physical system vary considerably and that to a

large degree materials are not substitutable because of their physical properties. Secondly, the approach requires an accurate and detailed representation of the processes through which materials must pass in order to become finished products. It is clear that the processes vary with materials; some processes require the combination or separation of materials; all processes require energy in varying quantities both for process heat and mechanical energy. Thus our model must be disaggregated both in materials space and activity space.

The physical orientation of the LTSM is achieved by basing the model on a highly disaggregated constant dollar Input-Output system. Resource use, labour demand, and capital requirements are all related technologically to sectoral gross production in constant dollars. Sectoral production is determined by industry technology and the complete set of transactions between sectors necessitated by the demand for final goods. Demand formation is largely driven by population, the major exogenous variables being per capita (constant dollar) consumer expenditures, investment levels, and total exports. The underlying population model starts with a recent population distribution and traces its evolution fairly mechanically using age-sex specific birth and death rates as well as the external effects of emigration and immigration; the major exogenous population variables are aggregate fertility and the rate of immigration. The overall dynamic behaviour of the model may be described by a forward recursion relation in the variable time.

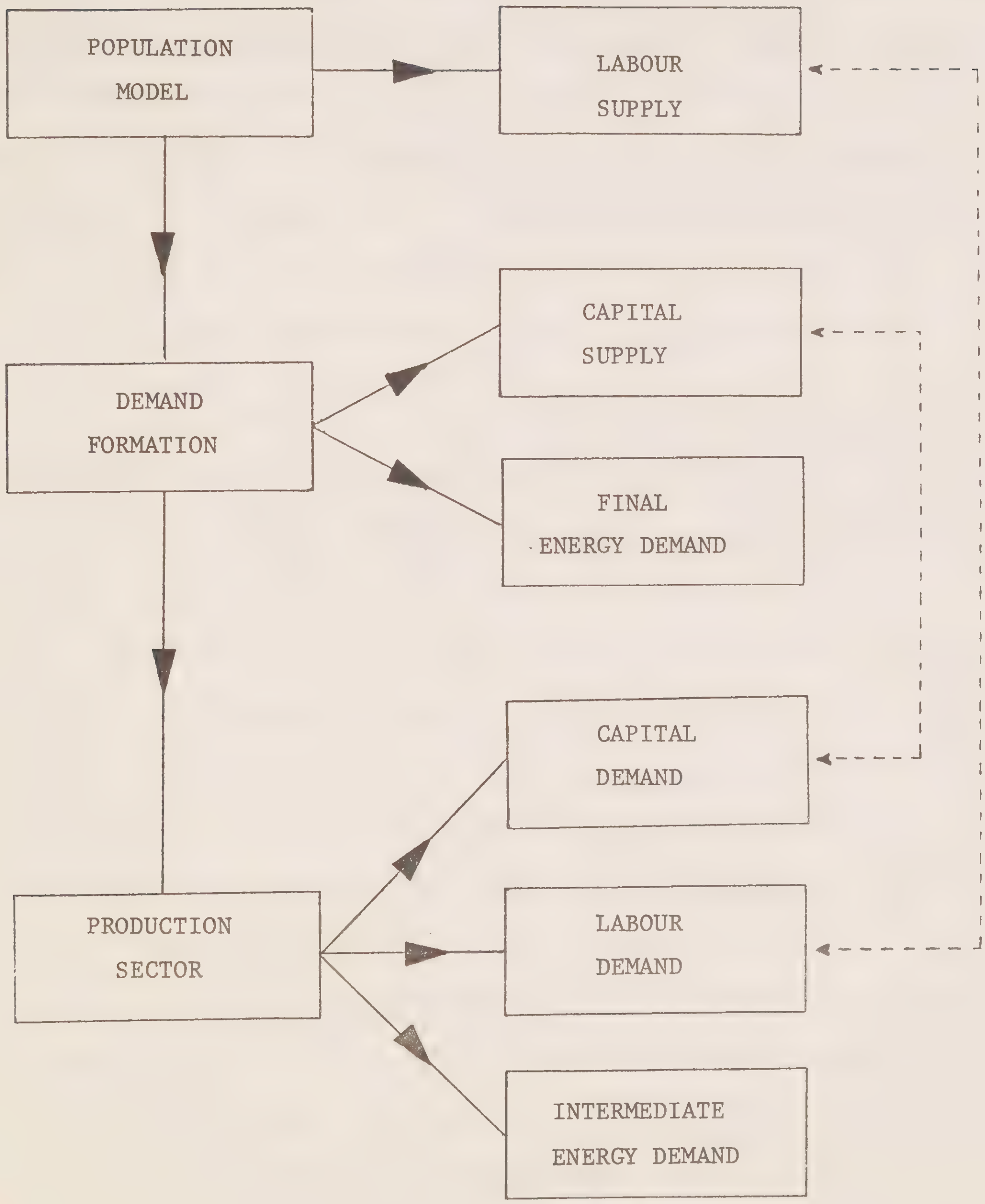
The name "Long Term Simulation Model" indicates two more important characteristics of the model. By "long term" is meant a time horizon of twenty to fifty years. In this time horizon the operative constraints on the economic system are essentially those imposed by the physical system: the availability of raw materials, energy, and labour, the ability of the system to accept waste material, and the physical laws governing transformations. The word "simulation" is used to indicate that the model is considerably open to user-specified reactions. As Figure I-1 shows, the model tracks supply and demand of both capital and labour separately, with no internal response to disequilibria. In the real world these responses are brought about by the collective decisions of all of the economic agents. In the model system the user of the model assumes the role of economic decision maker.

For a more detailed description of the LTSM as implemented the reader is referred to "Users Guide to the Statistics Canada Long Term Simulation Model" by R.B. Hoffman (Feb. 1977) and "Statistics Canada Long Term Simulation Model" by R.B. Hoffman, G. Sayant, and B. McInnis (Oct. 1976), both of which are available from the Structural Analysis Division.

The limitations of the model are inherent in what has been described so far. In the first place, this is a fixed technology model. Secondly, the use of constant dollars leads to particular difficulty in handling international trade, where relative price changes lead to some of the more interesting phenomena. And finally, it is not clear that the current National Accounts

FIGURE I-1

Model Schematic



concepts, particularly on the expenditure side, are appropriate for long term analysis.

As seen in Figure I-1, the LTSM has been configured to calculate energy demand. This is accomplished in physical units by means of a unit price transformation in the final demand sector, and by using historical physical consumption by fuel type for each industry in the production sector, assuming the use by each industry is fixed in proportion to gross production in constant dollars. There is no corresponding energy supply calculation as in the case of capital and labour. This is an essential block of the model which is under development.

As the title suggests, this study serves basically as a demonstration of the LTSM, with particular emphasis on its capability as an energy demand model. The examples presented should give the reader some feeling for how the factors of population, productivity, external trade, and final demand preference impact on Canadian energy resources, and how these impacts vary in their scope and importance. The paper demonstrates as well the two major modes of use of the LTSM: the scenario mode and the perturbation mode. Constructing a scenario corresponds to a choice of relatively few macro-variables, then observing and altering the behaviour of the model to achieve consistent results. Perturbations are built around a scenario by altering more micro-level variables while holding the major variables of the background scenario constant.

II The Scenarios

Three scenarios (labelled A, B, and C) have been developed for inclusion in this paper. These scenarios neither exhaust nor delimit the spectrum of evolutionary possibilities for the Canadian socio-economic system -- they are to be interpreted rather as examples of how the LTSM can be used. The three scenarios used identical demographic assumptions (low immigration and fertility by historical standards) and identical labour force participation rate scenarios (continuation of existing trends) but had varying assumptions about the growth of aggregate productivity. In scenario A, productivity grows more slowly than historical experience, with the rate decreasing until a zero-growth state is reached in the year 2000. In scenario C, on the other hand, productivity maintains a 2% rate of growth throughout the simulation interval. Scenario B falls roughly between these two extremes. In all three scenarios, international trade is set so that its relationship to GNE remains constant, i.e. in these scenarios the Canadian economy becomes neither more open nor more closed with respect to international trade. The structure of international trade, on the other hand, changes in all scenarios, the main features being that manufactured goods account for a higher proportion of exports, exports of oil and natural gas are phased out, and Canadian dependence on foreign oil decreases gradually to 30% by the year 2000.

On the consumption side, business investment is manipulated so as to maintain rough equality between available and required capital, government expenditures on health and education are tied

to population, and other government current expenditures maintain their historical relationship to consumer expenditures. Consumer expenditures themselves are set in such a way as to give rise to the aggregate productivity assumptions given earlier.

We shall now present in more detail the assumptions and results of the three scenarios.

Population; Households; Labour Supply

The chosen demographic scenario had a net immigration of 75,000 per year (gross immigration of 135,000 per year), and an asymptotic period total fertility rate of 1.80. A moderately conservative extrapolation of household headship rates was used, together with a 'medium' projection of historical trends with regard to labour force participation rates. The results in terms of population, households, and labour force are shown in Figure II-1. Rates of growth in the two 25 - year periods are shown in Table II-1.

As can be seen, households and labour force grow faster than population until the year 2000, after which growth rates of all three decrease. Other characteristics of the 'ageing' population, which approaches a steady-state as time progresses, can be viewed in Table II-2.

Both indicators reach extremal values roughly half way into the simulation interval, after which they reverse their directions of movement and re-approach their original values.

FIGURE II-1

MAJOR DEMOGRAPHIC VARIABLES

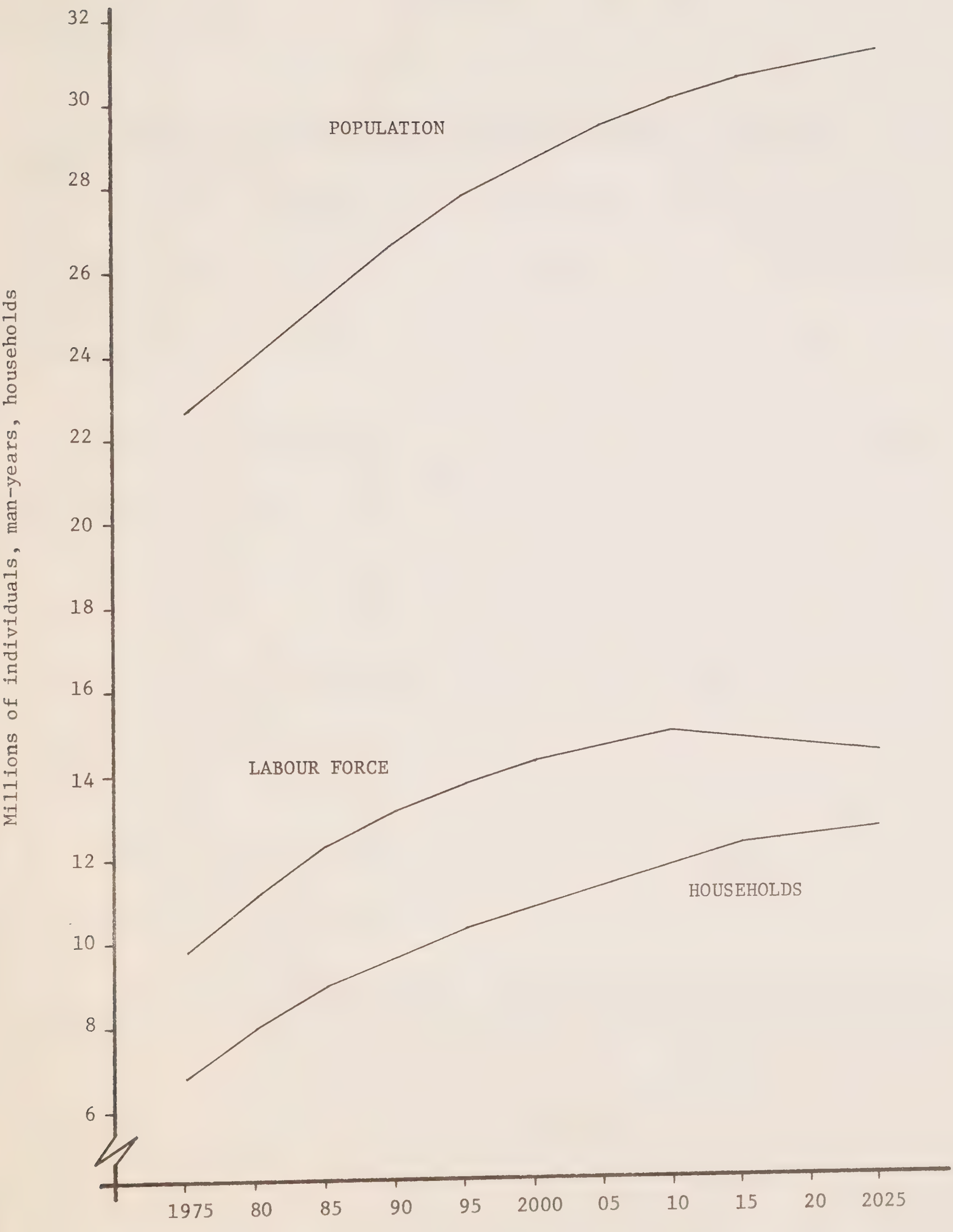


Table II-1

Rates of Growth of Selected Demographic Variables (% per year)

	Population	Households	Labour Force
1975-2000	0.94	1.86	1.52
2000-2025	0.35	0.64	0.05

Table II-2

Selected Demographic Indicators

	Overall Participation Rate (%)	Dependency * Ratio
1975	58.5	0.53
2000	63.0	0.46
2025	56.9	0.54

$$* \text{ Dependency ratio } = \frac{\text{(population less than 15 years + population greater than 64 years)}}{\text{(population from 15 to 64 years)}}$$

The fact that the original values are reapproached conceals, however, a fundamental change in the structure of the population. In 1975 the values of the indicators resulted from a preponderance of the young, whereas in 2025 the values result from a preponderance of old people. It should be noted that a higher immigration would have changed these results significantly. This issue is addressed in greater detail in section III below, where a perturbation with respect to immigration is presented.

Productivity

The assumptions regarding productivity are shown in Figure II-2. Aggregate productivity, together with an appropriate cyclically adjusted 'unemployment rate', allows the computation of aggregate production once one is given the supply of labour. This methodology is in contrast to the more usual demand-driven manner of using the LTSM, and was adopted to illustrate this mode of model use. The projected trends were chosen fairly arbitrarily and the sensitivity of all of the model results to these trends should be noted. It should also be noted that the concept of aggregate productivity subsumes under a single phrase many very difficult economic and sociological problems, with the result that the utility of the concept (as an exogenous variable) is more illusory than real. One has little choice but to do mechanical trend analysis when using such a concept.

FIGURE II-2

AGGREGATE PRODUCTIVITY

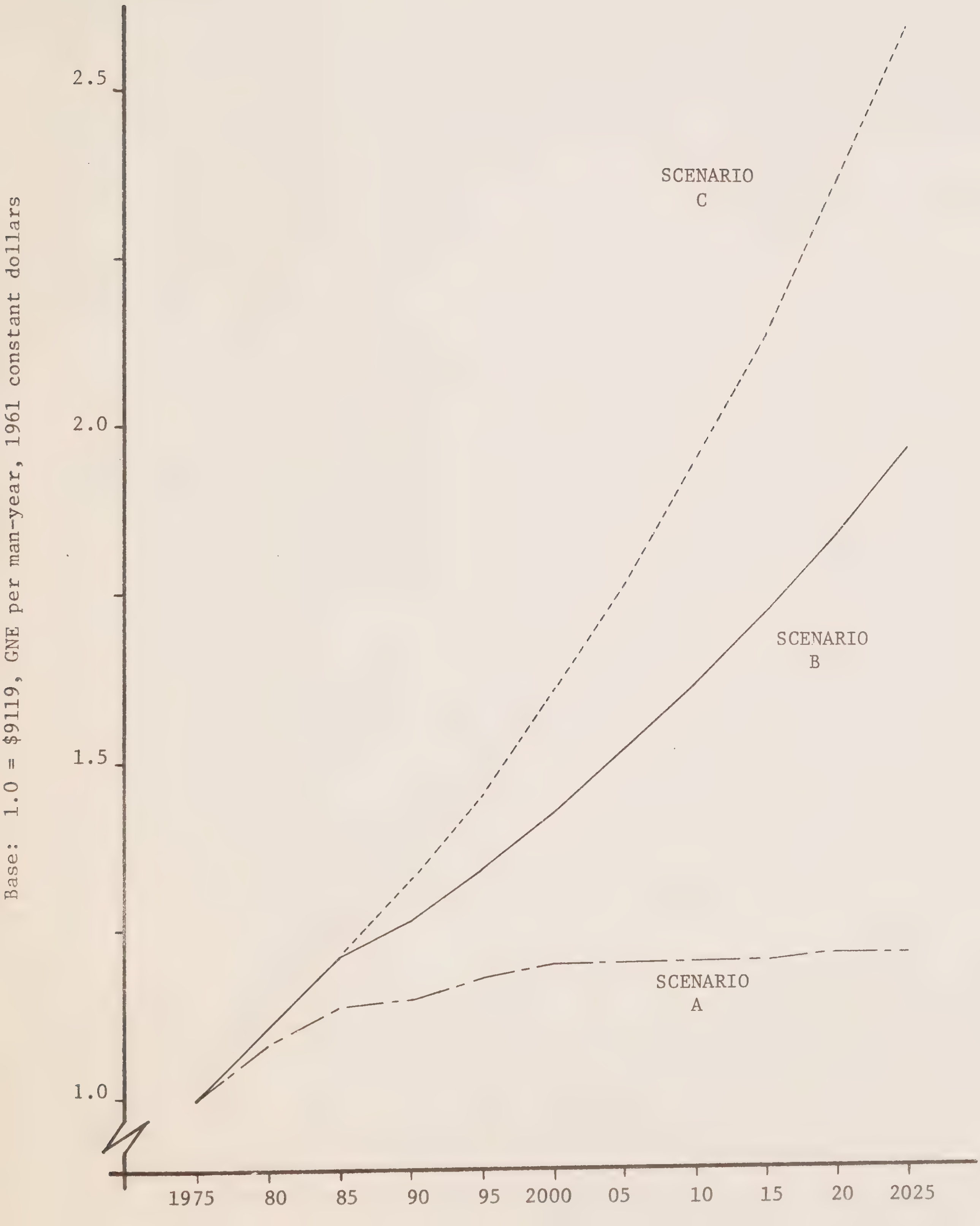
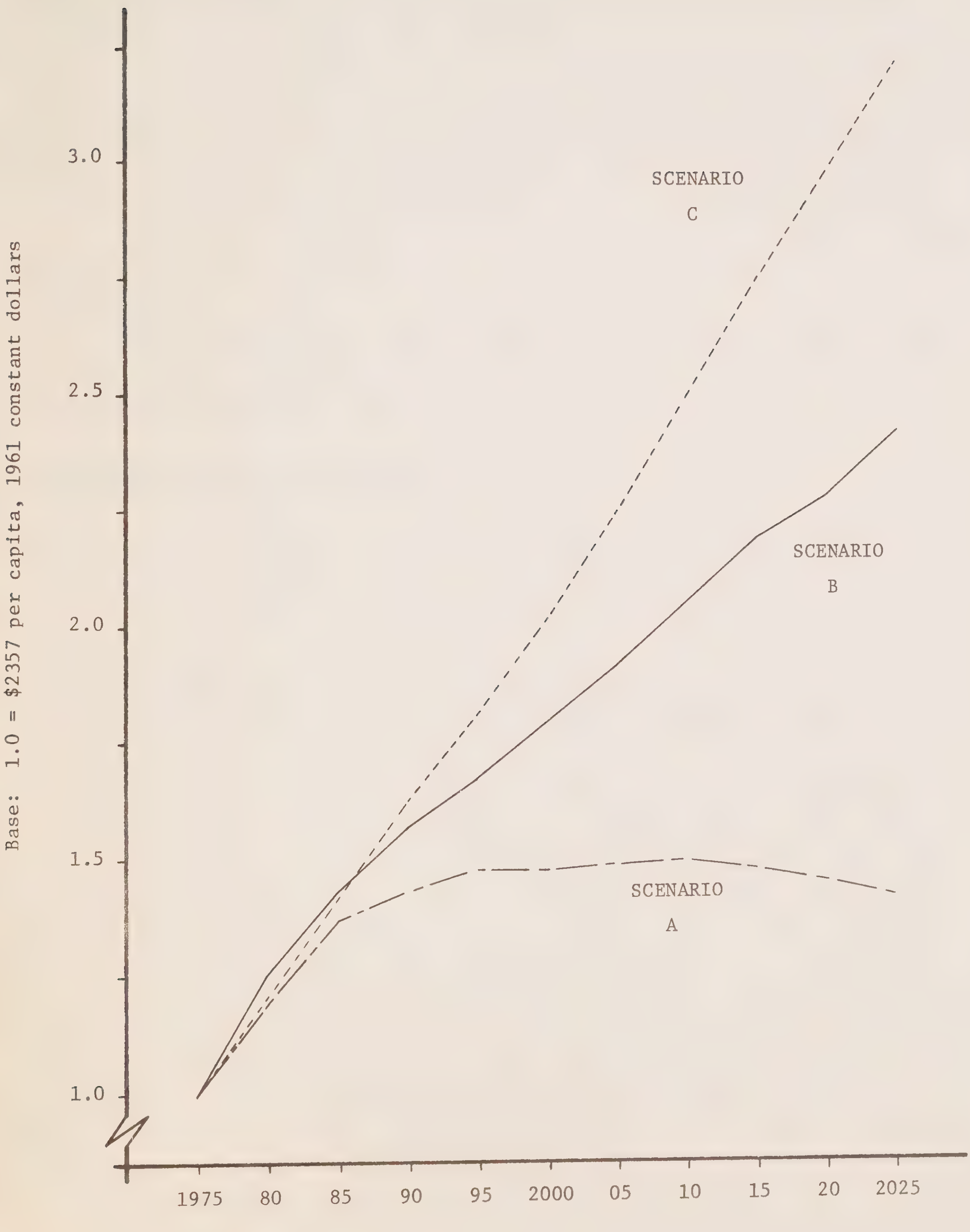


FIGURE II-3

CONSUMER EXPENDITURES PER CAPITA



Consumption

The values of consumer expenditure per capita associated with the three scenarios are shown in Figure II-3. While difficult to interpret meaningfully, the indicator nevertheless shows that a substantial difference in 'lifestyle' (as measured by the magnitude of per capita consumption flows) results from the underlying productivity assumptions.

Energy

Before presenting the results related to energy use, a few words about the underlying methodology are in order.

Energy Accounting Conventions

As a consequence of the fixed technology assumption to which the model is constrained presentation of results at the level of individual fuels would not be meaningful, given that there is a high probability of major fuel substitutions over the next fifty years. Accordingly the basic accounting convention employed is to total Joules of primary energy (fossil fuels being measured at roughly their internal energy of combustion). This is a reasonable procedure to the extent that one believes that one Joule of primary energy is as useful as another, the clear exception to this being hydro electricity which is convertible into work at about three times the efficiency of fossil fuels. Therefore, when presenting the components of energy supply and disposition the constituent electricity is counted entirely as

the Joules of primary thermal energy which would have been necessary for its production.

When measuring domestic resource base impacts the appropriate convention is again to measure Joules of primary energy, but it must be recognized that hydro electricity is, at least over a fifty year time span, a non-depletable resource. While hydro reserves will not deplete appreciably over this period of time, we could encounter a capacity constraint in terms of the number and size of viable hydro sites. The impact of total electric power demand (hydro and thermal) on the depletable resource base is, therefore, calculated as follows:

(i) until an assumed hydro-electric capacity limit is reached, a fixed share (20%) of electricity demanded is considered to be thermally generated, with consequent impact on Canadian resources;

(ii) an estimate of ultimate hydro capacity being twice the 1975 output is employed;

(iii) once this capacity limit is reached, on the basis of fixed technology and a fixed thermal electric share, every additional Joule of electricity is considered to be thermally generated from Canadian resources.

Another energy accounting convention concerns the treatment of imported energy. Any figures presented on imported energy

represent displaced Canadian primary thermal energy. Thus, an imported secondary energy crossing the border is valued not at its thermal equivalent but rather as the primary Canadian thermal energy which would have been required to produce it had it not been imported.

The components of energy supply and disposition are based on the following building blocks:

ID – the <u>industrial demand</u> in Joules of primary energy.

FU – the <u>final use</u> in Joules of primary energy.

X – the <u>exports</u> in Joules of primary energy.

M – the <u>imports</u>, measured as displaced domestic primary energy.

Employing these blocks, and recognizing that the model is strictly a demand model, the <u>domestic production</u> is defined by the following identity:

$$DP = ID + FU + X - M$$

<u>Net Domestic Production</u> is given by:

$$NDP = DP - X$$

<u>Domestic Disposition</u> by:

$$DD = ID + FU$$

<u>Domestic Supply</u> by:

$$DS = DP + M - X = DD$$

Total Disposition by:

$$TD = ID + FU + X$$

Total Supply by:

$$TS = DP + M = TD$$

Of all of these concepts domestic disposition is the one which most closely measures the response of the Canadian economy, with its inherent technologies, to the domestic demand for goods and services. The independence of this measure from the more volatile direct trade terms (X and M) makes it a useful basis for comparing scenarios. However, it should be noted that this figure is not independent of the structure of international trade: the patterns of non-energy commodity imports and exports affect the domestic disposition of energy independent of domestic demand for all goods and services.

Energy Results

The composition of domestic supply and disposition of energy is given in Figures II-4, II-5, and II-6. The reader is reminded that the values of energy imports result from the assumption that crude oil imports will decrease as a proportion of total use until a figure of 30% is reached.

Figures II-7 and II-8 indicate the trends in Canadian non-renewable energy use expected under the three scenarios. It should be noted that the impact of non-hydro renewable energy sources, (such as solar energy or breeder reactor technology) is

FIGURE II-4

COMPOSITION OF DOMESTIC SUPPLY AND DISPOSITION - SCENARIO A

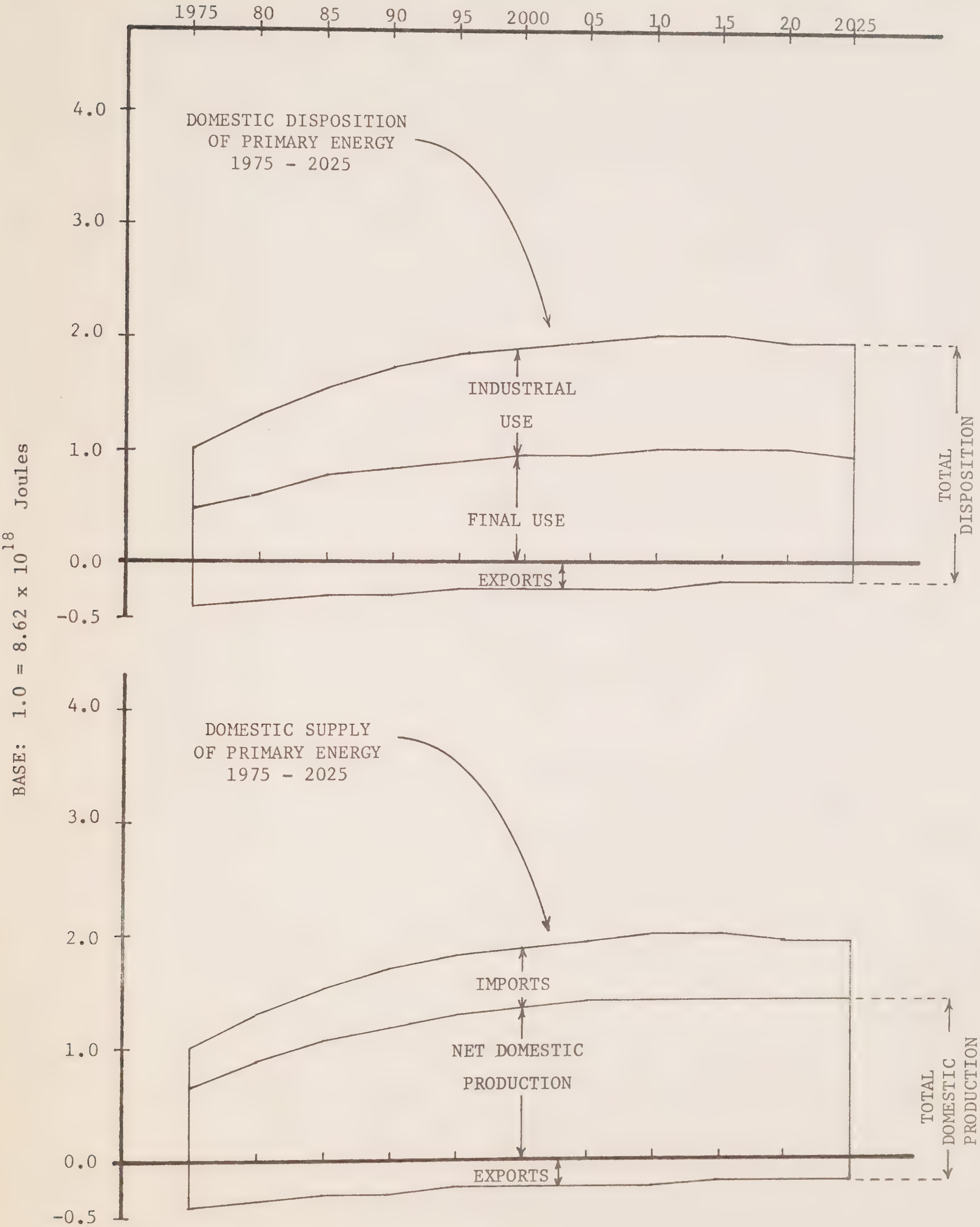


FIGURE II-5

COMPOSITION OF DOMESTIC SUPPLY AND DISPOSITION - SCENARIO B

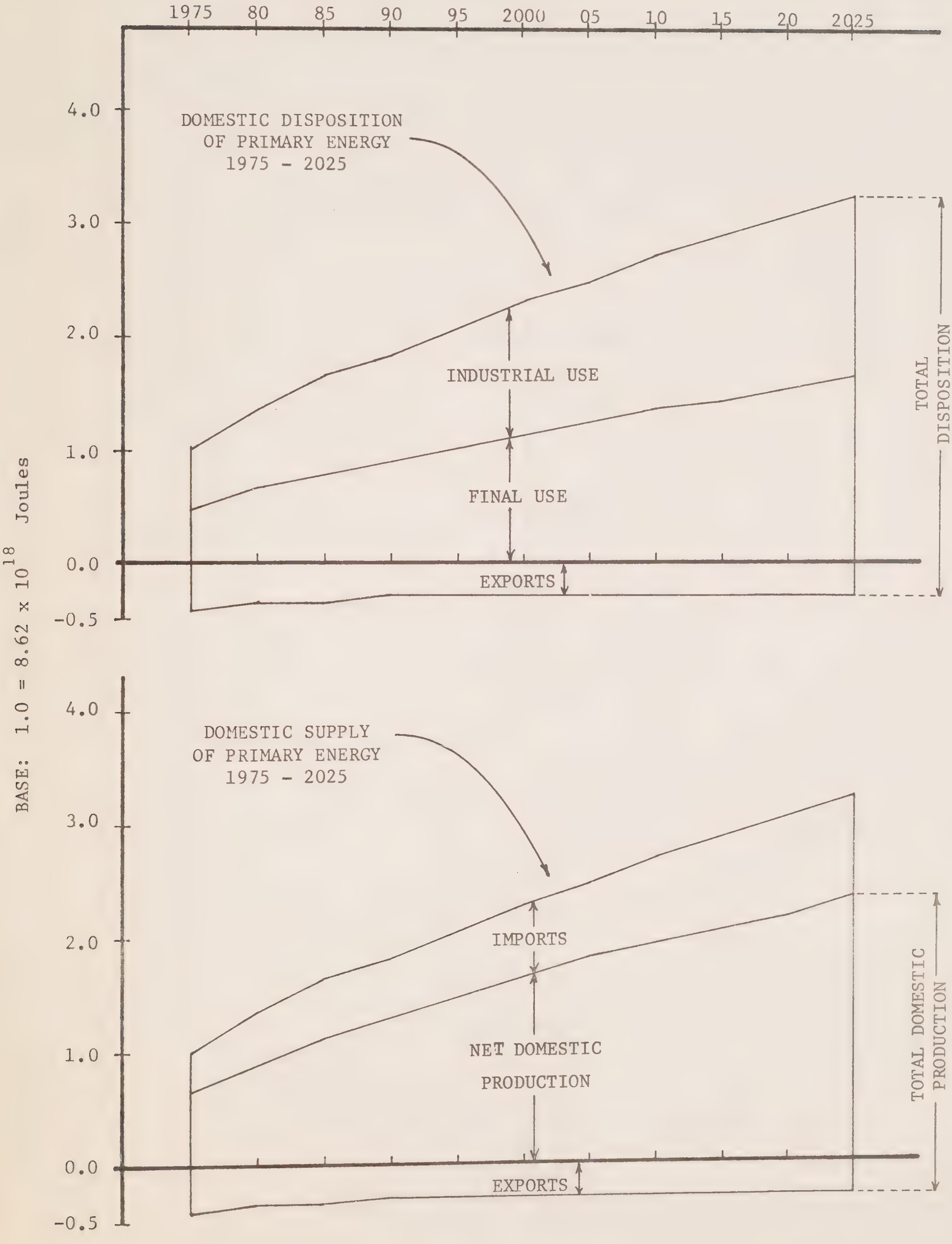


FIGURE II-6

COMPOSITION OF DOMESTIC SUPPLY AND DISPOSITION - SCENARIO C

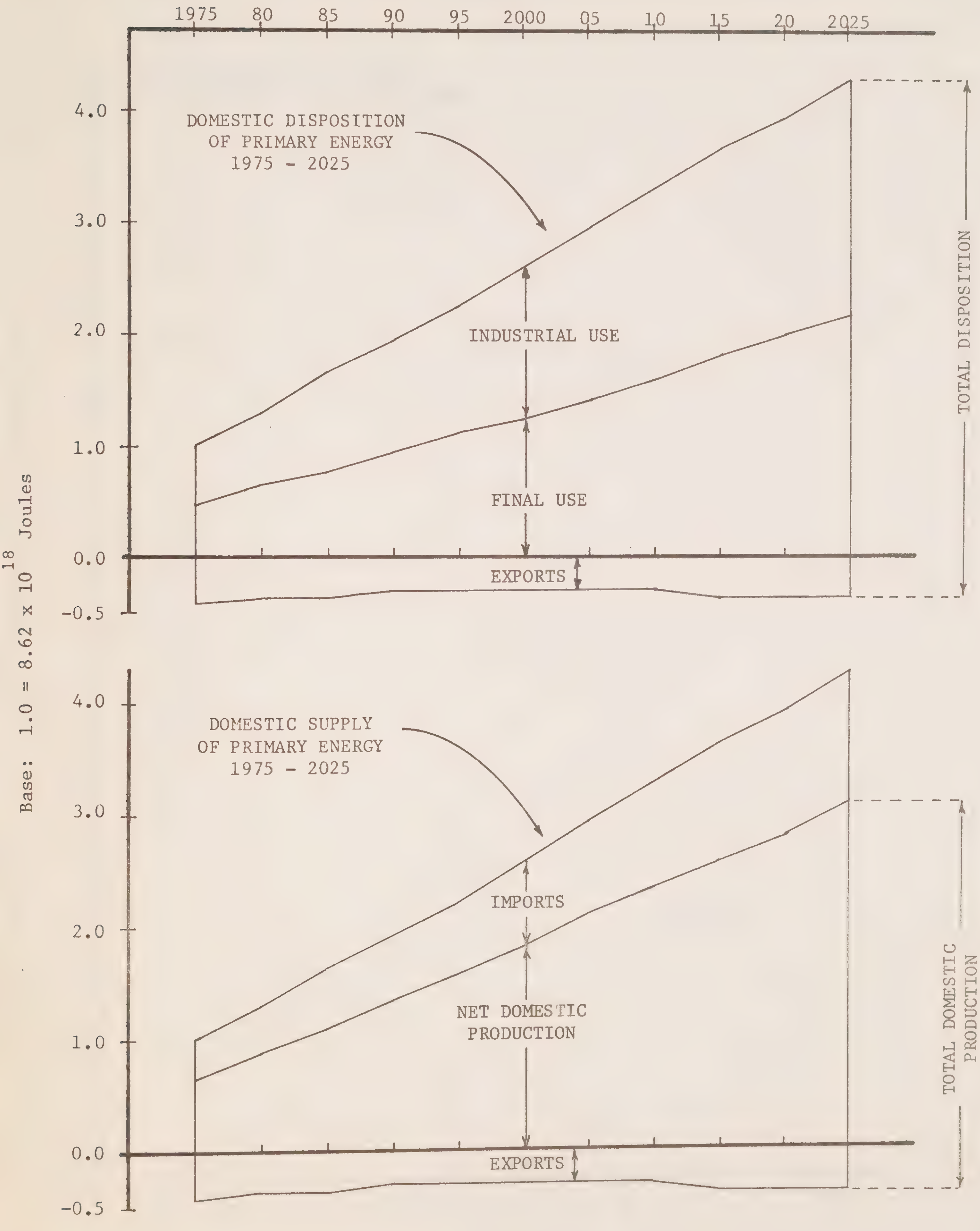


FIGURE II-7

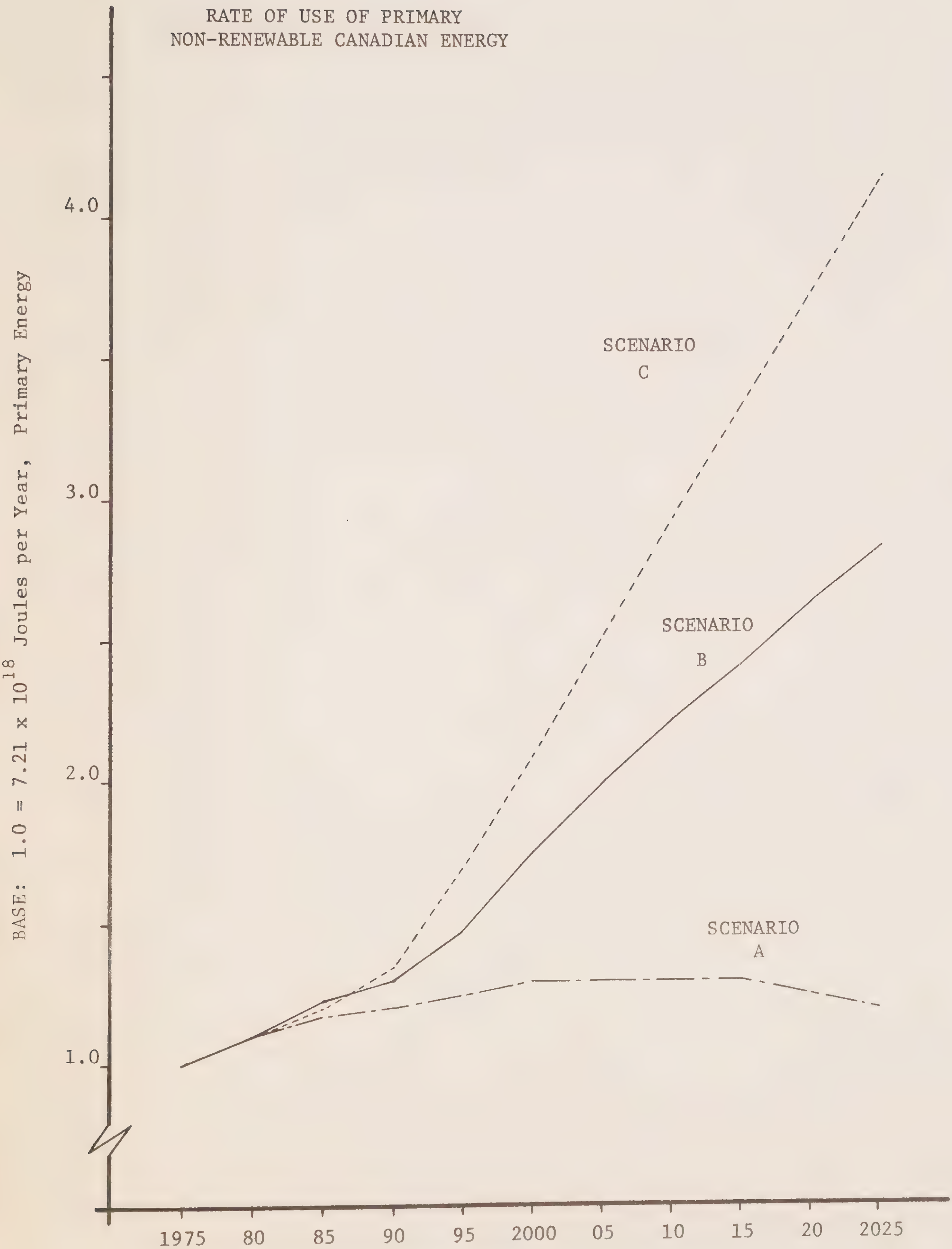
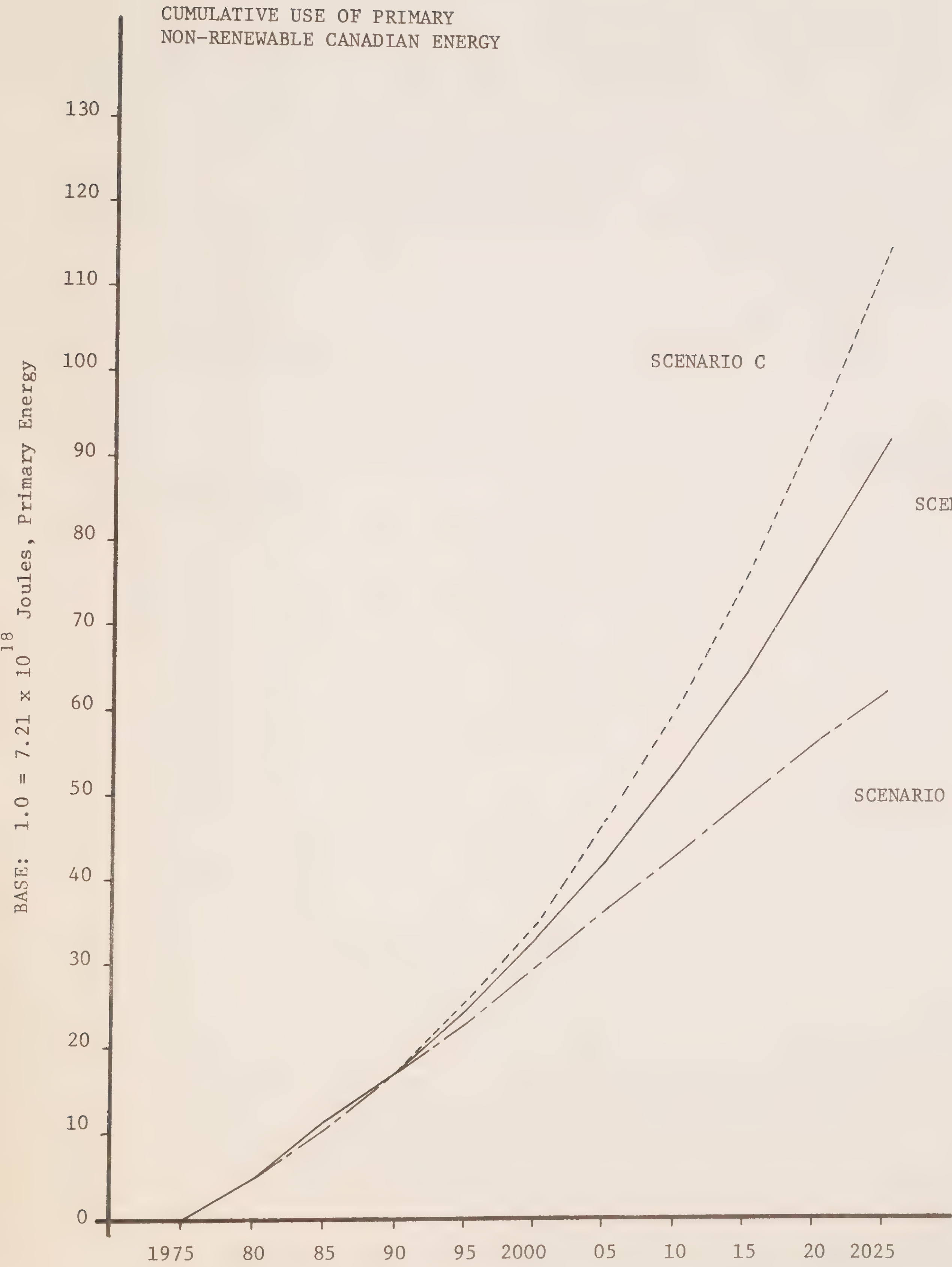

RATE OF USE OF PRIMARY
NON-RENEWABLE CANADIAN ENERGY
BASE: 1.0 = 7.21 x 10^18 Joules per Year, Primary Energy
4.0
3.0
2.0
1.0
SCENARIO C
SCENARIO B
SCENARIO A
1975
80
85
90
95
2000
05
10
15
20
2025

FIGURE II-8


CUMULATIVE USE OF PRIMARY
NON-RENEWABLE CANADIAN ENERGY
BASE: 1.0 = 7.21 x 10^18 Joules, Primary Energy
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1975
80
85
90
95
2000
05
10
15
20
2025
SCENARIO C
SCENARIO B
SCENARIO A

not accounted for in the figures shown. With a fair degree of certainty, it can be expected that such renewable energy sources will in fact account for a significant proportion of energy supply within the time frame under consideration. Also ignored are the (probably important) effects of anticipated energy conservation. An interesting conclusion can nevertheless be drawn from Figure II-7, namely, that if consumption trends can in fact be kept in line with resources of renewable energy, disproportionate savings of non-renewable energy result. It bears remarking that the level of per capita consumption in scenario A has an asymptotic value about 50% higher than that observed in the year 1975, despite the modest growth in domestic energy requirements.

III - The Perturbations

As an example of one of the important modes of use of the LTSM a series of variants or perturbations of the B scenario were run, involving changes in some of the major exogenous parameters of the model. The perturbations have the following names:

i) the immigration variant

ii) the energy trade variant

iii) the trade openness variant

iv) the energy final consumption variant

v) the terms of trade variant.

What follows is a brief description of the characteristics distinguishing each perturbation from the B scenario.

The Immigration Variant alters only the demographic sub-model of the B scenario, increasing immigration by a constant 25,000 per year, and leaving all other demographic variables unchanged. Per capita consumption levels and the other exogenous variables from scenario B remain constant.

The Energy Trade Variant involves a phasing out of direct trade in energy commodities. After 1975 both exports and imports decrease at an approximate average annual rate of 9%, leaving trade at about 1% of the 1975 level by 2025.

The Trade Openness Variant measures the effects of increasing the openness of the Canadian economy to external trade. The ratio of the total value of exports to GNE is increased linearly from 0.25

in 1975 to 0.30 in 2025. Of course trade remains balanced in each simulation period.

<u>The Energy Final Consumption Variant</u> examines the effects of fixing the per household expenditures on energy and the per capita expenditures on motor gasoline at their 1980 levels, while allowing all other consumer expenditures to track the same values as occur in scenario B. Final expenditures on energy in this variant therefore follow population growth almost exactly (there being a marginally greater rate of growth of households than of population in the B demographic scenario).

<u>The Terms of Trade Variant</u> considers an increase in the price of Canadian exports relative to imports. The variation achieves this through a linearly decreasing value of exports relative to scenario B, until the year 2000 scenario B exports are 105% of the exports in this variant. This ratio to scenario B exports is maintained from the year 2000 onward, while imports are held to their scenario B level for all years.

Presentation of Results

The general philosophy in summarizing results of the perturbation analyses is to present for each variant those elements of energy supply and disposition which are most clearly distinguished from the scenario B results. This procedure is necessary owing to the disproportionate effects particular perturbations have on certain energy variables. The emphasis is on the energy consequences of the perturbations not only because

energy impacts are the principal focus of this study, but also because the effects on other variables are largely obvious from the description of the variant. The exception to this is the immigration variant, where selected demographic variables are given to complement the energy results.

(i) <u>Canadian Depletable Primary Energy</u>

From a policy viewpoint the "bottom line" in any long term energy scenario is the annual rate of use of Canadian depletable primary energy, which, when accumulated, leads to the extent of depletion over the particular time horizon. These values are given in Figure III-1 for the rate of use, and Figure III-2 for the cumulative use, to the year 2025. The base for these figures is the 1975 rate of use of Canadian depletable primary energy.

For reasons to be discussed later, the trade openness and terms of trade variants are indistinguishable on this scale and have therefore been grouped under the title "trade variants." These and the immigration variant produce quite modest changes from the B scenario. The energy trade variant indicates a very high Canadian energy cost associated with an energy self-sufficiency policy as compared with the 30% import dependency of scenario B; in fact the use of Canadian depletable primary energy is higher than for scenario C up to 2025. The energy final consumption variant indicates the dramatic energy savings entailed by fixing per capita energy final consumption. The use of Canadian depletable primary energy in this variant only begins to exceed that for scenario A beyond the year 2000.

FIGURE III-1

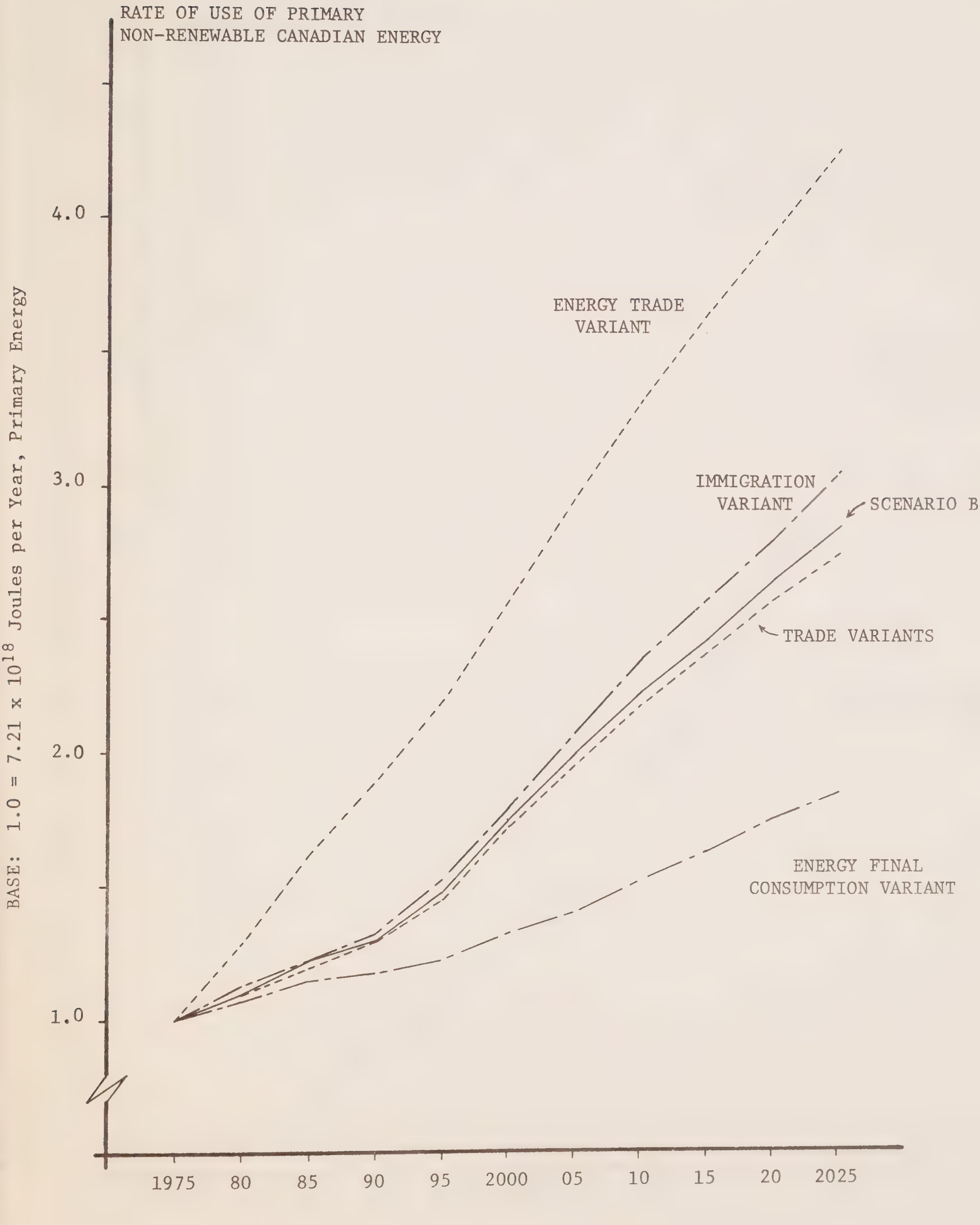

RATE OF USE OF PRIMARY
NON-RENEWABLE CANADIAN ENERGY
BASE: 1.0 = 7.21 x 10^18 Joules per Year, Primary Energy
4.0
3.0
2.0
1.0
ENERGY TRADE
VARIANT
IMMIGRATION
VARIANT
SCENARIO B
TRADE VARIANTS
ENERGY FINAL
CONSUMPTION VARIANT
1975
80
85
90
95
2000
05
10
15
20
2025

FIGURE III-2

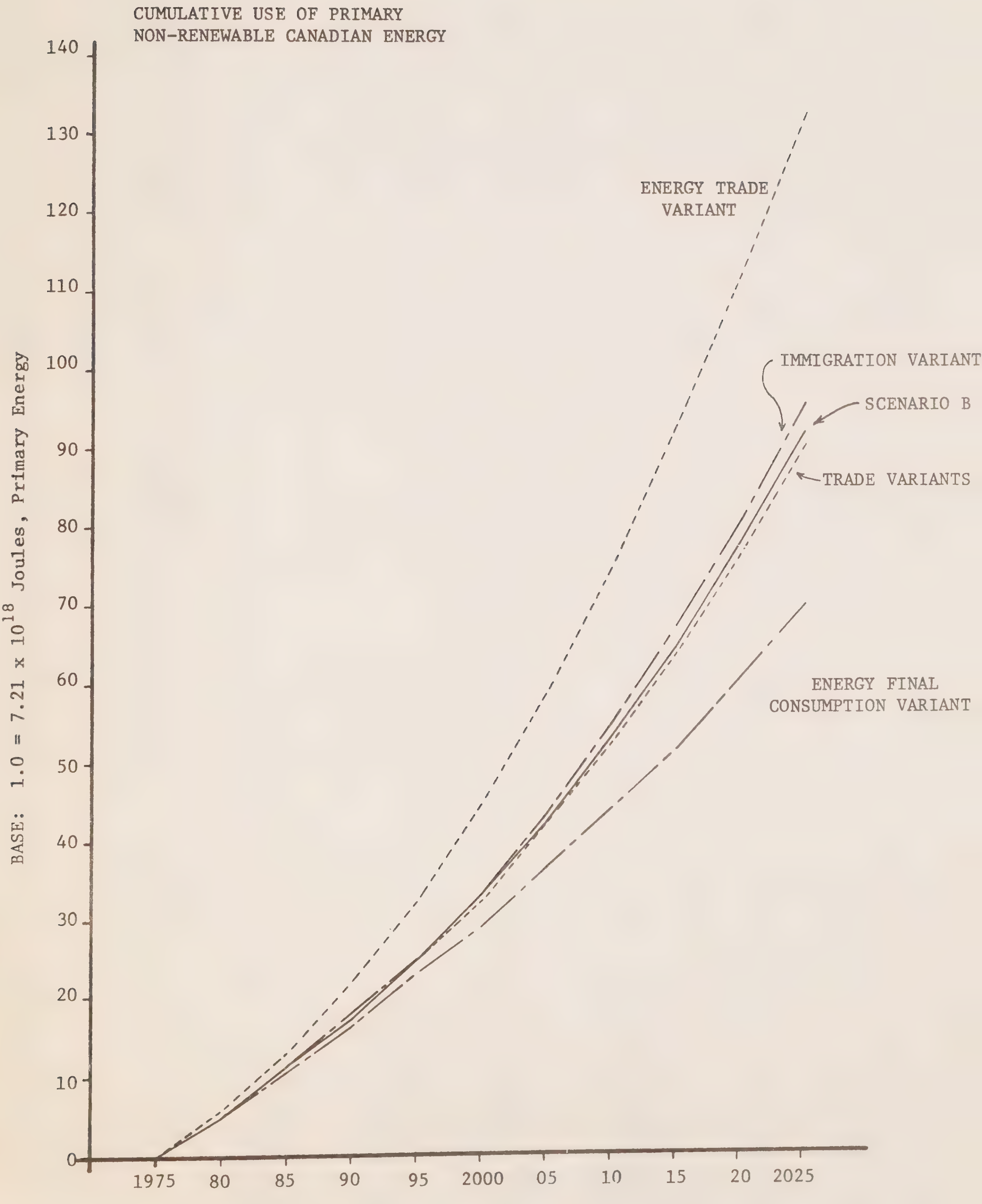

CUMULATIVE USE OF PRIMARY
NON-RENEWABLE CANADIAN ENERGY
BASE: 1.0 = 7.21 x 10^18 Joules, Primary Energy
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
1975
80
85
90
95
2000
05
10
15
20
2025
ENERGY TRADE
VARIANT
IMMIGRATION VARIANT
SCENARIO B
TRADE VARIANTS
ENERGY FINAL
CONSUMPTION VARIANT

Table III-1

Rates of Growth of Disposition and Domestic Energy Use

	Scenario B	Variants: Immigration	Direct Energy Trade	Trade Openness	Energy Final Consumption	Terms of Trade
Domestic Disposition	Base: 1.0 = 8.62×10^{18} Joules.					
1975	1.00	1.00	1.00	1.00	1.00	1.00
Ave. Annual Rate of Growth	3.22%	3.32%	3.33%	3.22%	2.49%	3.19%
200	2.21	2.26	2.27	2.21	1.85	2.19
Ave. Annual Rate of Growth	1.44%	1.53%	1.46%	1.45%	1.01%	1.44%
2025	3.16	3.30	3.26	3.17	2.38	3.13
Domestic Non-Renewable Primary Energy Rate of Use	Base: 1.0 = 7.21×10^{18} Joules.					
1975	1.00	1.00	1.00	1.00	1.00	1.00
Ave. Annual Rate of Growth	2.24%	2.40%	3.86%	2.19%	1.12%	2.15%
2000	1.74	1.81	2.58	1.72	1.32	1.70
Ave. Annual Rate of Growth	2.01%	2.12%	2.04%	1.91%	1.36%	2.00%
2025	2.86	3.06	4.27	2.76	1.85	2.79

Table III-2

Exports and Imports of Primary Energy

Base: $1.0 = 3.18 \times 10^{18}$ Joules

	Scenario B		Fuel Trade Variant	
	Exports	Imports	Exports	Imports
1975	1.07	1.00	1.07	1.00
Avg. Annual Rate of Growth	-1.68%	2.10%	-8.98%	-7.95%
2000	0.70	1.68	0.10	0.13
Avg. Annual Rate of Growth	0.17%	1.40%	-8.73%	-9.82%
2025	0.73	2.38	0.01	0.01

The variants, together with scenario B, are summarized in terms of numbers in Table III-1. In addition, since the fuel trade variant is the only one exhibiting significant changes in direct energy trade, the figures for exports and imports appear in Table III-2.

(ii) The Domestic Supply and Disposition of Energy

There are three variants which display distinct changes in the composition of domestic supply and disposition. The first of these, the immigration variant, displays only a slight increase in all components relative to the B scenario, as shown in Figure III-3 (the base for this and the following three Figures is the 1975 domestic disposition of primary energy). Figure III-4 is the composition diagram for the energy trade variant. Here the major effects are on the supply side: by the year 2025 domestic production equals domestic supply, which in turn is equal to total disposition. Figure III-5 demonstrates a sectoral redistribution of energy disposition: in the energy final consumption variant the industrial use assumes an increasing fraction of domestic disposition over time, in contrast with scenario B where this fraction is nearly constant at 50%.

Another useful comparison of the energy final consumption variant, with scenario A, is shown in Figure III-6. It is evident from this Figure that even for very moderate per capita GNE growth rates, as exhibited by scenario A, the domestic disposition of primary energy to the year 2000 exceeds that for a

FIGURE III-3

COMPOSITION OF DOMESTIC SUPPLY AND DISPOSITION - IMMIGRATION VARIANT

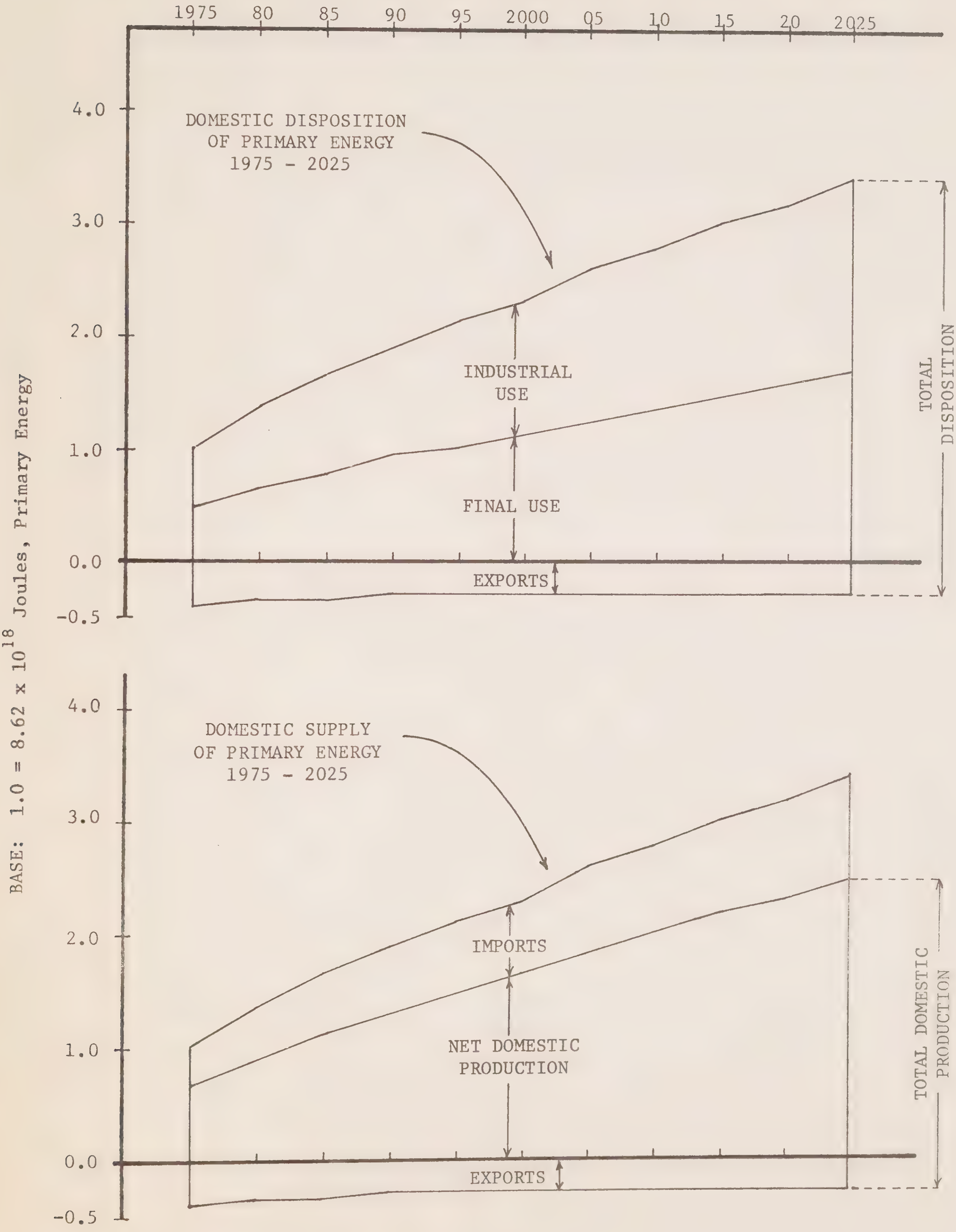


FIGURE III-4

COMPOSITION OF DOMESTIC SUPPLY AND DISPOSITION - ENERGY TRADE VARIANT

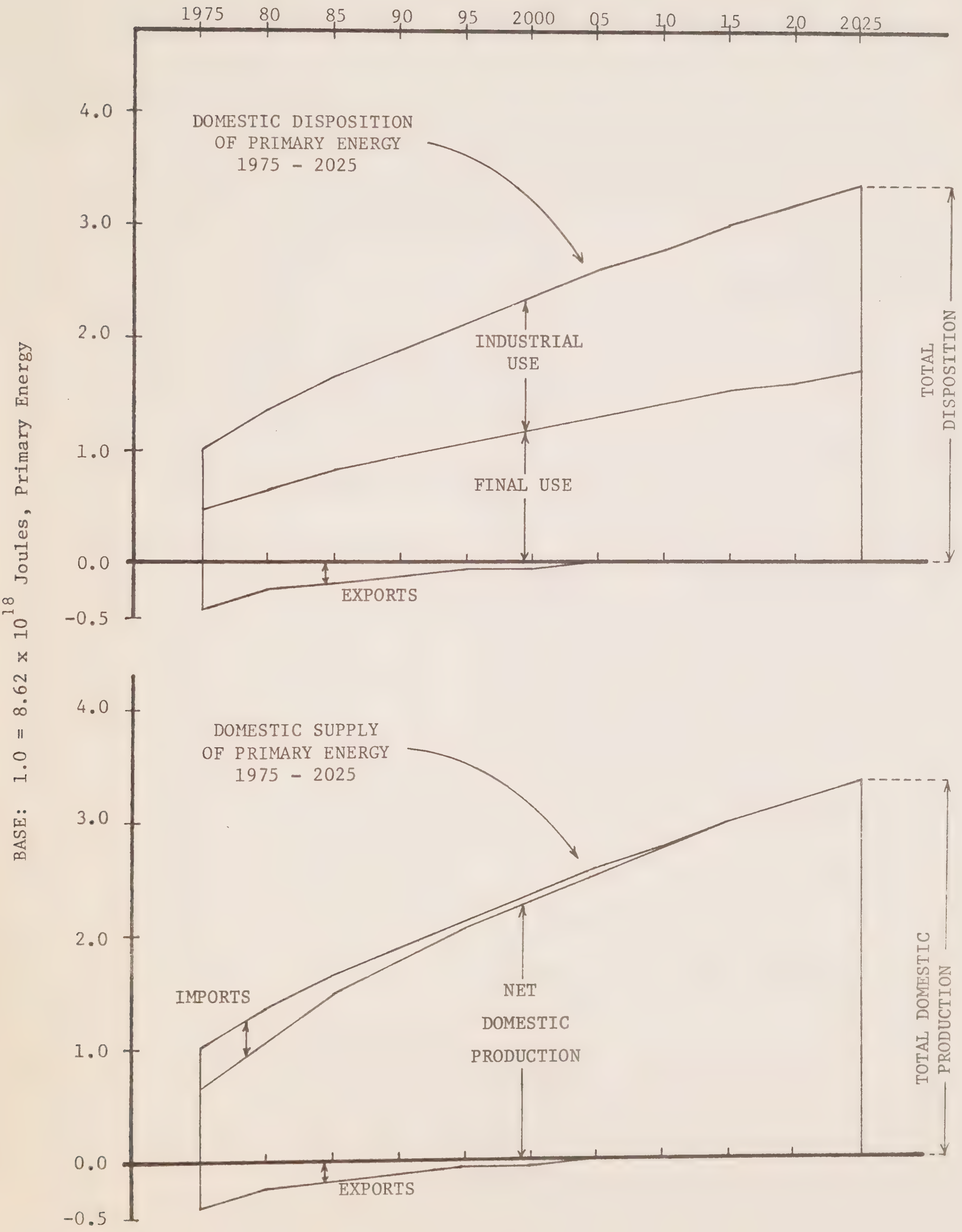


FIGURE III-5

COMPOSITION OF DOMESTIC SUPPLY AND DISPOSITION - ENERGY FINAL CONSUMPTION VARIANT

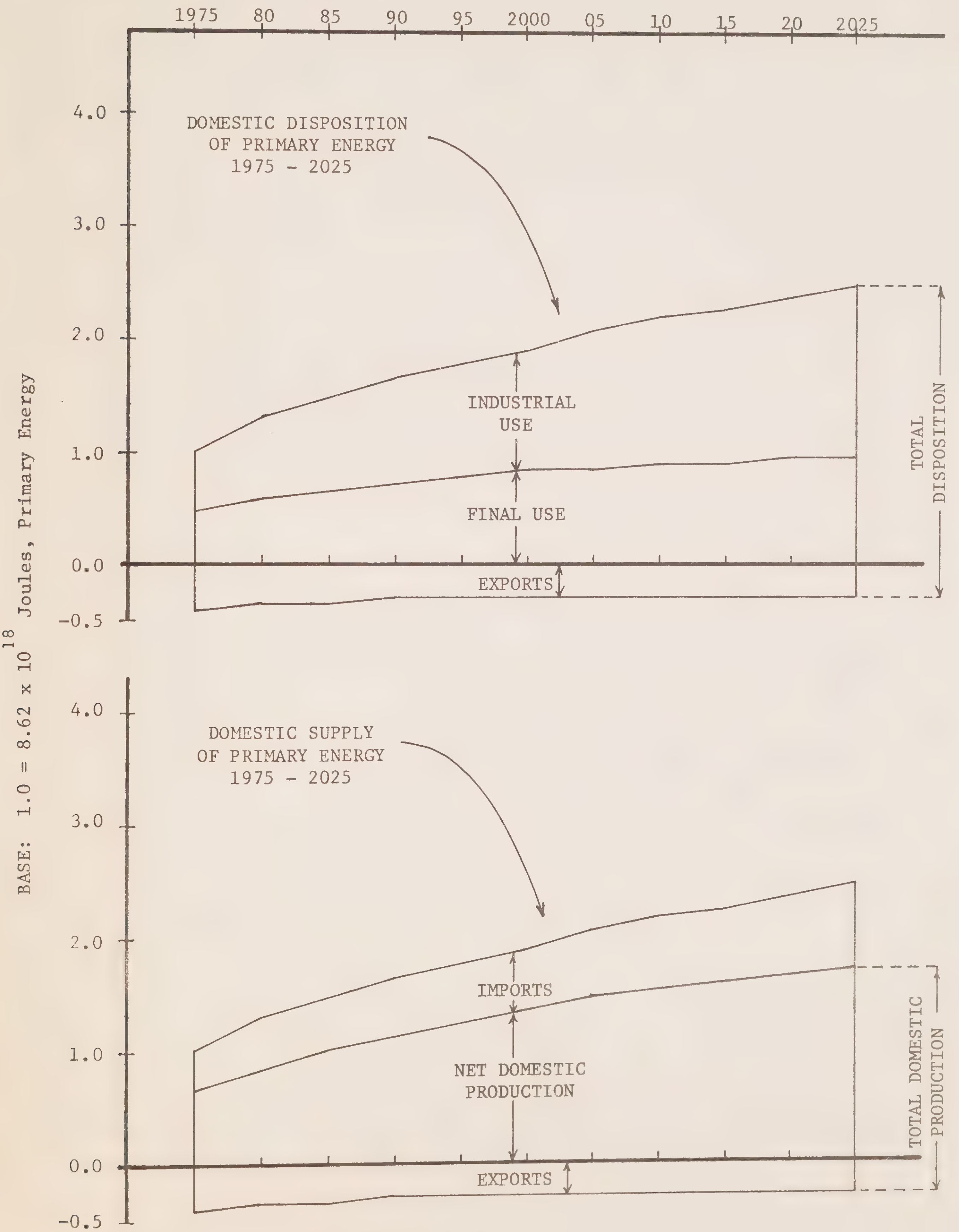
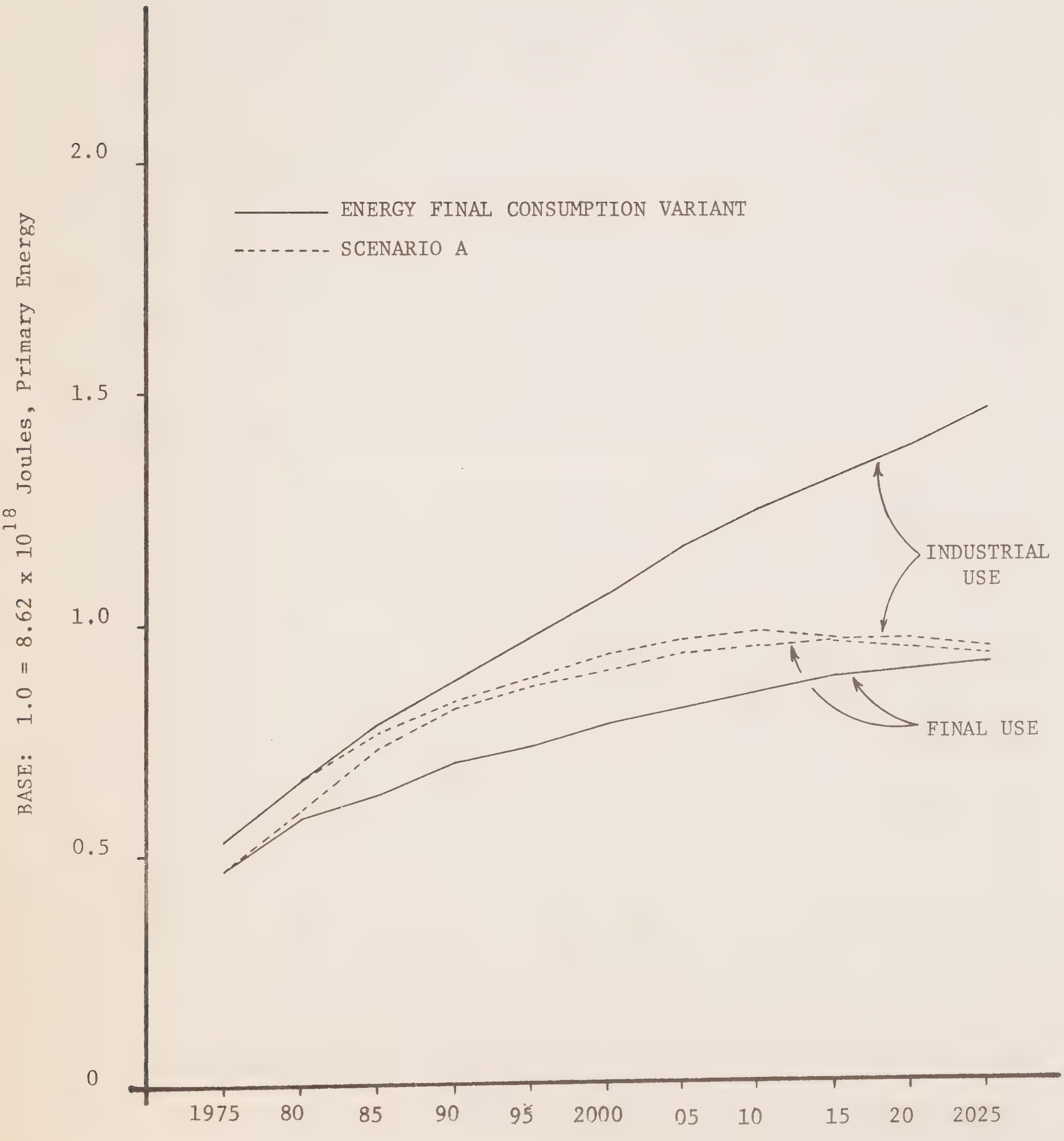


FIGURE III-6

COMPARISON OF INDUSTRIAL USE AND FINAL USE



higher growth scenario in which final consumption of energy is restrained.

(iii) The Immigration Variant

To give some idea of the effect of annual immigration being increased by a constant 25,000 people, Table III-3 gives figures for six major demographic variables: population, households, labour force, dependency ratio, persons per household, and labour force participation. Aside from the obvious population increase resulting from increased immigration, all the changes observed may be attributed to the fact, given that immigrants are assumed to behave precisely like natives once they have entered the country, that the immigrant age-sex distribution is dominated by individuals in the prime employment and reproduction years.

Starting from any base year, in this case 1975, it is possible to conceptualize the immigrant and indigenous populations as separate groups, growing and working independently. Whereas the indigenous population grows only according to its birth and death rates, the immigrant population has in addition a replenishment of new immigrants each year. If this influx is limited to being some constant, N thousands, with a fixed age-sex distribution in each year, then it is clear that the immigrant population is homogenous in N. Assuming that final demand is a linear function of population age-sex categories, which is true for this model, it is therefore possible to define immigration multipliers, or rates of change of variables with respect to rates of immigration which are constant over time.

Table III-3

Major Demographic Variables

	Population (millions)		Households (millions)		Labour Force (millions)	
	Scenario B	Immigration variant	Scenario B	Immigration variant	Scenario B	Immigration variant
975	22.675	22.700	6.865	6.872	9.836	9.849
vg. Annual ate of Growth	0.94%	1.05%	1.86%	1.96%	1.52%	1.63%
000	28.666	29.446	10.880	11.151	14.339	14.771
vg. Annual ate of Growth	0.35%	0.45%	0.64%	0.73%	0.05%	0.15%
025	31.277	32.922	12.746	13.367	14.509	15.352

	Dependency Ratio		Persons Per Household		Labour Force Participation Rate	
	Scenario B	Immigration variant	Scenario B	Immigration variant	Scenario B	Immigration variant
1975	.533	.532	3.303	3.303	58.53%	58.54%
2000	.455	.453	2.635	2.641	63.00%	63.21%
2025	.541	.535	2.454	2.463	56.87%	57.20%

Table III-4

Immigration Variant - Rates of Change

All figures are per 1000 immigrants per year.

Demographic Variables

	2000	2025
Population	31200	65800
Labour Force	17300 man-years	33700 man-years
Dependency ratio	-0.00008	-0.00024
Participation rate	0.0084 %	0.0132 %

Energy Variables

	2000	2025
Domestic Disposition	0.018	0.050
Domestic Non-renewable Energy Rate of Use	0.020	0.058
Domestic Non-renewable Primary Energy Cumulative Use (measured from 1975)	0.182	1.139

The multipliers are themselves functions of time, and Table III-4 presents some sample demographic and energy multipliers for 2000 and 2025. Table III-4 may be read as follows: if there were a constant 100,000 immigrants per year from 1975 on, then the rate of use of domestic primary energy would increase by 2.0×10^{18} Joules in 2000, and by 5.8×10^{18} Joules in 2025, as compared with a scenario with no immigration.

(iv) The Trade Variants

As noted earlier, measures such as domestic disposition or cumulative use of domestic non-renewable energy turned out to be too aggregated to distinguish the trade openness and terms of trade variants. Figure III-7 plots the categories of energy supply and disposition which best illustrate the differences between these variants (the base for this Figure is the 1975 domestic disposition of primary energy). To the extent that the structure of non-energy commodity trade in the scenarios remains that Canadian exports are more energy intensive than Canadian imports per constant dollar, then the variation in industrial disposition shown in Figure III-7 fits our expectation of the trade perturbations. To make these differences much clearer, the deviation from scenario B of industrial disposition in each variant is shown in Figure III-8 (whose base is the 1975 industrial disposition of primary energy). By 2025 the difference in industrial disposition for the two variants is less than 9% of the 1975 industrial use of primary energy. The relatively minor size of this variation is probably due to the

FIGURE III-7

TRADE VARIANTS: INDUSTRIAL DISPOSITION, IMPORTS, EXPORTS

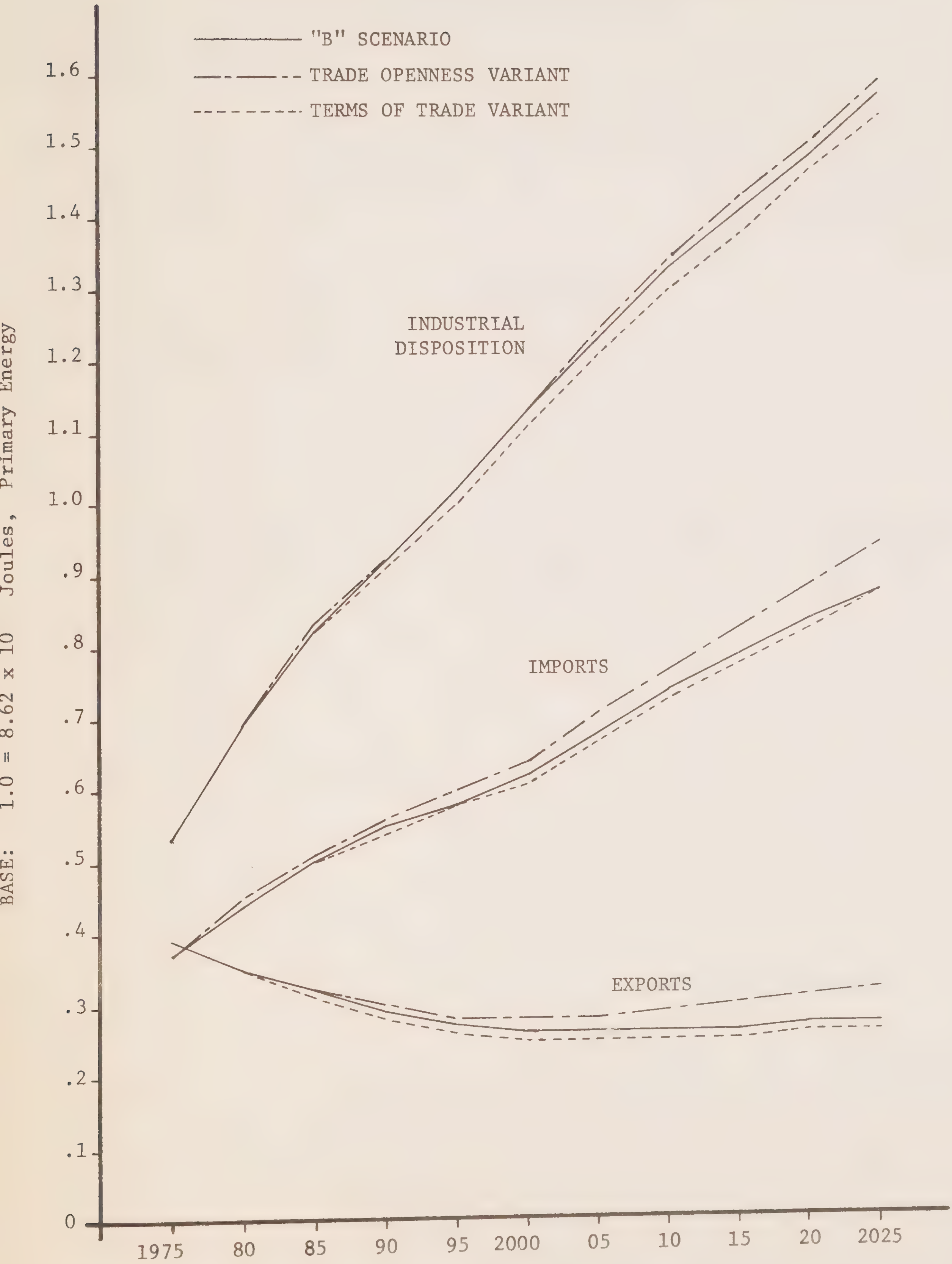
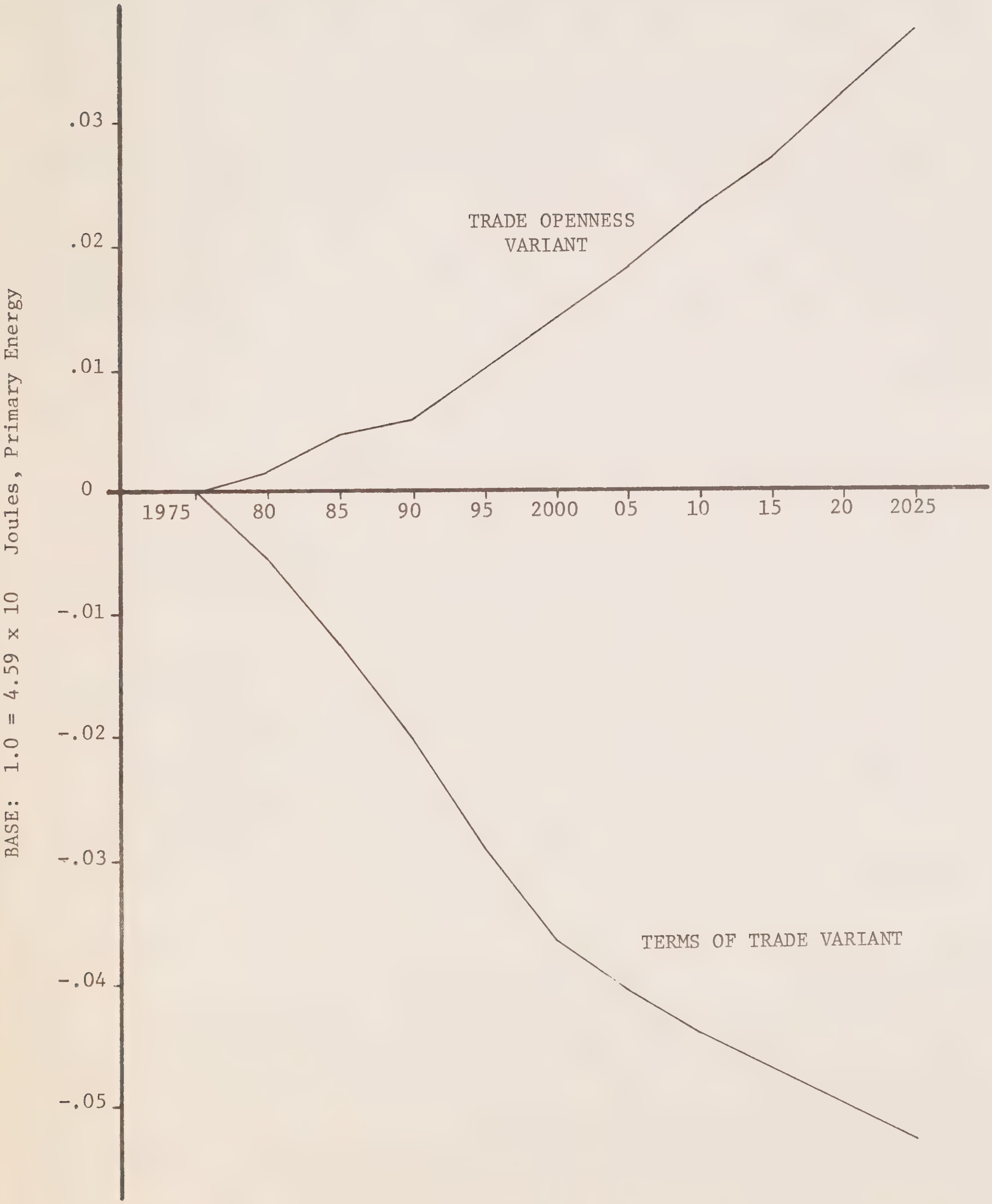


FIGURE III-8

CHANGE IN INDUSTRIAL DEMAND
(Relative to Scenario B)



patterns of commodity imports and exports becoming more similar over time in the B scenario.

With the exception of the energy trade variant all scenarios and perturbations "control" exports and imports of energy on the following basis: exports of oil and natural gas decline at about 9% per year, and imports of crude oil stabilize at 30% of domestic disposition in the year 2000. It follows that some of the variations in imports and exports evident in Figure III-7 arise from uncontrolled energies which were originally (i.e. in 1975) very minor portions of energy trade. The evident asymmetry of increased imports exceeding increased exports of energy in the trade openness variant is owing to both the marginal effects of the uncontrolled energies and the built-in asymmetry of the control of exports and imports. This spurious result is sufficient to lead to the indistinguishability of the trade variants displayed in Figures III-1 and III-2.

Summary of Results

The following remarks on the results of the perturbation analyses tend in some instances to be substantive, where the model results merit, in other instances pragmatic, speaking to inadequacies or difficulties in using the model for perturbation analysis.

The immigration results demonstrate that increasing immigration, all other things being equal, increases energy use; for this no model is required. However, the immigration multipliers, for which a model <u>is</u> necessary, do indicate the size

and sign of change in demographic and energy variables in relation to immigration. As such the model demonstrates its possible usefulness in the formation of demographic policy in Canada: it can be used to indicate the hypothetical demand effects of population scenarios.

The trade openness and terms of trade variants exemplify some of the difficulties in using the model in the perturbation mode. Where the effects of the perturbations on the variables of interest are liable to be small, some care must be taken in specifying the simulations. The difficulties encountered in this study may be grouped under the general headings of masking, asymmetry, and inertia. Changes in the structure of commodity trade in the simulations tended to mask the impact of the perturbation on industrial disposition. Combined with the attenuating effects of this masking, the asymmetry of controls on energy imports and exports led to a surprising direction of change in one of the major variables, the rate of use of non-renewable domestic primary energy. And finally, the fact that the initially insignificant uncontrolled energies came to dominate the exports and imports of primary energy indicates how the inertia of the system can, given sufficient time, produce unreasonable or at least unexpected results, in the sense that these energies grow "by default".

For all the simulations except the energy trade variant, imported primary energy was fairly stable at about 30% of domestic supply. Whether this is to be viewed as high import dependence hinges on two considerations: security of supply and

balance of payments effects. Admitting such considerations to be outside the scope of this study, the fact remains that, comparing the cumulative use of depletable domestic primary energy for scenario C and the energy trade variant, continued energy import dependence of 30% would allow a future with relatively high economic growth (scenario C) having roughly the same impact on the non-renewable resource base as one with significantly lower economic growth but achieving energy self-sufficiency (the energy trade variant).

The energy final consumption variant displays large energy savings (relative to scenario B) ensuing from a fairly conservative assumption: that per capita energy usage be projected to its 1980 level and fixed thereafter. It is worth reiterating that these energy savings occur with exactly the same final expenditures on all other goods and services as in scenario B. All other simulations treat consumer expenditures on energy as if they were technologically constrained in the same sense as energy expenditures in the steel industry or any other, i.e. primary energy for final consumption is fixed in proportion to total consumer expenditures exactly as primary energy in the steel industry is fixed in proportion to the value of output. In fact the distribution of commodities in the bill of goods making up consumer expenditures is constrained not by technology but by preference. Once the population has satisfied all its desires for the basic services which direct consumption of energy provides, notably heating, lighting, and transportation, it may well attach higher value to spending each additional unit of

income on other, non-energy, goods, and it is precisely this which the energy final consumption variant simulates.